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TECHNICAL NOTE
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EXPERIMENTAL INVESTIGATION OF THE PRESSURE FLUCTUATIONS ON A FLAT PLATE AND A CYLINDER IN THE SLIPSTREAM OF A HOVERING ROTOR

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EXPERIMENTAL INVESTIGATION OF THE PRESSURE FLUCTUATIONS ON A FLAT PLATE AND A CYLINDER IN THE SLIPSTREAM OF A HOVERING ROTOR

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SUMMARY

An experimental study has been made of the pressure fluctuations on bodies in the slipstream of a hovering rotor. The slipstream was generated by a 6-foot-diameter two-blade rotor with constant-chord untwisted blades. Pressures were obtained for a 12-inch square plate and a 12-inch-diameter cylinder for a range of positions in the slipstream with the plate and the cylinder axis parallel to the rotor disk.

The surface pressures on the models, referenced to undisturbed atmospheric pressure, were found to have high positive peaks at blade-passage intervals. The peak pressures were most pronounced when the models were positioned close to the plane of the rotor and the pressure orifices were near the edge of the slipstream where they were subject to the highest slipstream dynamic pressure. There were progressive changes of the character of the pressures with change of orifice position around the cylinder (from upwind to downwind) and with change of position in the slipstream. Some complex periodic pressures and random pressures were found in the tests.

INTRODUCTION

In the case of a hovering helicopter, the fuselage and other parts are generally at least partially immersed in the rotor slipstream. The air loads imposed on surfaces and bodies in a rotor slipstream can be important from considerations of loss of net thrust or of the pulsating nature of the loads. The results from previous investigations (refs. 1 to 3) have shown in some detail the magnitude of the drag loads of cylinders and flat plates in a rotor slipstream for simulated hovering conditions. Also in reference 2 the air loads on a flat plate were found to be periodic, high peaks occurring at blade-passage intervals. The magnitude of the peak loading, as shown by recorded surface pressures, diminished with distance from the plane of the rotor.

The present investigation was undertaken primarily to obtain pressure data for a cylindrical body (representative of fuselage shape) similar to that obtained for flat plates in reference 2. The effects of model position in a rotor slipstream were obtained for two models used in the drag investigation of reference 3, a cylinder and a square flat plate.

SYMBOLS

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p_a	undisturbed atmospheric pressure, lb/sq ft
p	pressure at model orifice, lb/sq ft
r	radial distance of model orifice station from center of rotor, ft
R	rotor radius, ft
T	rotor thrust, lb
z	distance from rotor plane of zero flapping to flat-plate model or to center line of cylindrical model, ft

APPARATUS AND TEST PROCEDURE

A 6-foot-diameter two-blade rotor with constant-chord untwisted blades (chord of 0.33 foot, solidity of 0.071) was used to generate a slipstream in a sheltered outdoor location (see fig. 1). Details of the rotor, rotor drive system, and test area were as described in reference 3. The model shown in figure 1 was not part of the present investigation but had the same length and width as the cylinder that was tested.

A sketch of the models tested showing the location of the pressure measurement orifices is given in figure 2. One model was a 12-inch square plate made of aluminum. This plate was mounted parallel to the plane of the rotor disk with three orifices in the surface of the plate that faced toward the rotor. Miniature electrical pressure gages (ref. 4) were attached to the other (or back) surface of the model at each orifice and were referenced to ambient atmospheric pressure by a tube that extended well outside the rotor slipstream. The other model, representative of a fuselage, was a cylinder 72 inches long and 12 inches in diameter. Seven surface pressure orifices and gages were equally spaced around a semicircumference located 15.5 inches from one end of the cylinder. These gages were also referenced to ambient atmospheric pressure. The axis of the cylinder was perpendicular to the rotor shaft axis.

Data were obtained with the models at several fixed distances from the plane of the rotor (z/R) for a range of traverse positions (r/R). All tests were run at a rotor speed of 1,167 ± 3 revolutions per minute and a blade pitch angle of 11°. The resulting coning angle was approximately 2°, the tip speed was 367 feet per second, and the average disk loading (thrust per unit disk area) was 1.93 pounds per square foot. The signals from the electrical pressure gages were recorded by an oscillograph. The frequency-response characteristics of the equipment were such that response was flat to 600 cycles per second with some fall-off in response to 800 cycles per second.

RESULTS AND DISCUSSION

Flat Plate

Pressure data for the 12-inch square flat plate were obtained for five radial positions from $r/R = 0$ to 1.0 for distances from the rotor plane z/R of 0.111 and 0.333. Samples of the recorded data are presented in figure 3. The recorded data show peak pressure pulses at blade-passage frequency as was noted in reference 2. Differences in recording sensitivities existed for the pressure gages and the pressures cannot be compared directly in figure 3. The maximum and minimum pressures referenced to undisturbed atmospheric pressure, as identified in figure 3, were reduced to coefficient form by dividing them by rotor disk loading and these data are presented in figure 4. Although these data are limited in scope, it is clear that they follow the trends that were found in reference 2. The level of the maximum pressure is high when the plate is close to the plane of the rotor and the level rises as the pressure orifices are moved from the center of the rotor slipstream toward the edge. There is approximate agreement with the pressure data of reference 2 if the pressure traces are considered, as in that report, to consist of pressure pulses superimposed on steady-state pressures, the pulses being reduced in terms of disk loading per blade rather than disk loading.

Cylinder

Pressure data were obtained for axial traverses of the 12-inch-diameter cylinder across the slipstream wake at various distances from the rotor (z/R equal to 0.278, 0.389, 0.500, and 0.611). Samples of the recorded data are presented in figure 5. The trace sensitivities are different for the different orifices. The characteristic pressure peak at blade-passage frequency for orifice 1 (this orifice is on a cylinder radius directed toward the plane of the rotor) is of greatest magnitude when the orifice station is near $r/R = \pm 0.8$ and the cylinder is close to the rotor ($z/R = 0.278$). There are progressive changes in the shape of the pressure trace with change of orifice position around the cylinder (orifice 7 is on a downwind cylinder radius) and with change of r/R and z/R. Very complex periodic pressures and random (nonperiodic) pressures exist for the survey range as the result of flow separation on the cylinder and the variety of flow conditions existing in the slipstream.

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Maximum and minimum pressures, referenced to undisturbed atmospheric pressure, were reduced to coefficient form by dividing them by rotor disk loading and these data are presented in figure 6. Orifice 1 was 6 inches (cylinder radius) closer to the rotor than was the cylinder axis; thus, when the cylinder axis was at $z/R = 0.278$, orifice 1 was the same distance from the rotor as the plate when the plate was at z/R of 0.111. (See fig. 4.) The data of cylinder orifice 1 (this orifice should experience essentially stagnation pressure) show much more completely than figure 4 the variation of the positive pressure peaks throughout the rotor slipstream. For traverses close to the rotor the distribution is very similar to the slipstream dynamic-pressure survey of reference 3, an added factor being negative pressure peaks just outside the edge of the slipstream ($r/R = 0.93$). The level of the positive pressure peaks of orifice 1 is comparable with the flat-plate data of figure 3. The data of orifice 1, if examined as pulses reduced in terms of disk loading per blade superimposed on steady-state values, in general agree closely with that of reference 2, some disagreement in values occurring near the edge of the slipstream.

The maximum and minimum pressure coefficients are progressively modified as the orifice location moves around the cylinder from position 1 (upwind) to 7 (downwind). The data are not mirror images about $r/R = 0$. The location of the orifice station near one end of the cylinder resulted in different amounts of cylinder in the slipstream for plus and minus values of r/R. Slipstream rotation would also introduce a differential flow-separation effect on opposite sides of the rotor.

CONCLUDING REMARKS

Surface pressures were measured for a 12-inch square plate and a 12-inch-diameter cylinder for a range of positions in a slipstream generated by a 6-foot-diameter rotor. The surface pressures on the models, referenced to undisturbed atmospheric pressure, were found to have high positive peaks at blade-passage intervals. The peak pressures were most pronounced when the models were positioned close to the plane of the rotor and the pressure orifices were near the edge of the slipstream where they were subject to the highest slipstream dynamic pressure. There were progressive changes of the character of the pressures with change of orifice position around the cylinder (from upwind to downwind) and with change of position in the slipstream. Some complex periodic pressures and random pressures were found in the tests.

L Langley Research Center,
6 National Aeronautics and Space Administration,
0 Langley Field, Va., July 20, 1959.
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REFERENCES

1. Fail, R. A., and Eyre, R. C. W.: Loss of Static Thrust Due to a Fixed Surface Under a Helicopter Rotor. Tech. Note No. Aero. 2008, British R.A.E., July 1949.

2. Makofski, Robert A., and Menkick, George F.: Investigation of Vertical Drag and Periodic Airloads Acting on Flat Panels in a Rotor Slipstream. NACA TN 3900, 1956.

3. McKee, John W., and Naeseth, Rodger L.: Experimental Investigation of the Drag of Flat Plates and Cylinders in the Slipstream of a Hovering Rotor. NACA TN 4239, 1958.

4. Patterson, John L.: A Miniature Electrical Pressure Gage Utilizing a Stretched Flat Diaphragm. NACA TN 2659, 1952.

L-601

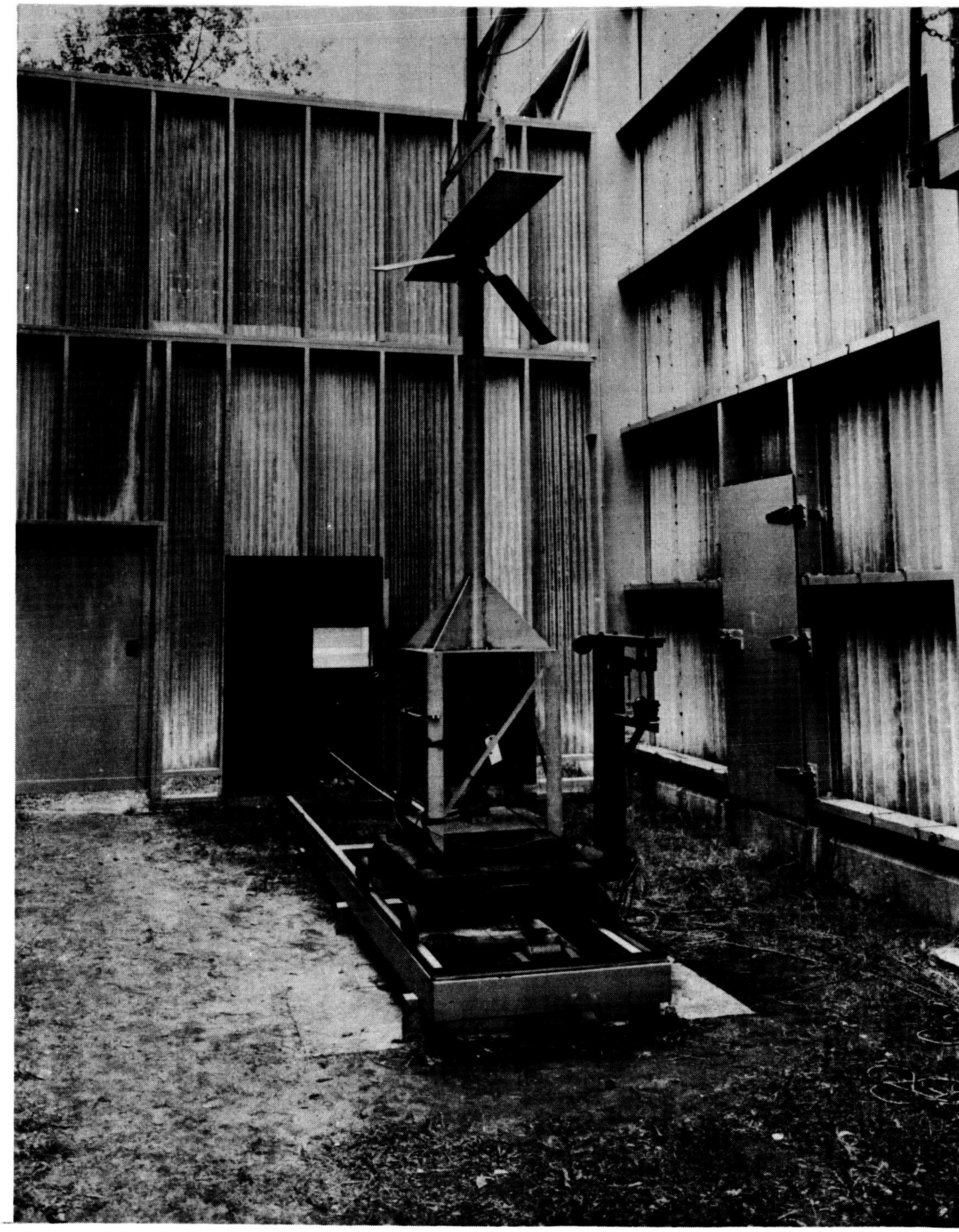

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Figure 1.- The rotor apparatus. The flat-plate model is not part of the present investigation.

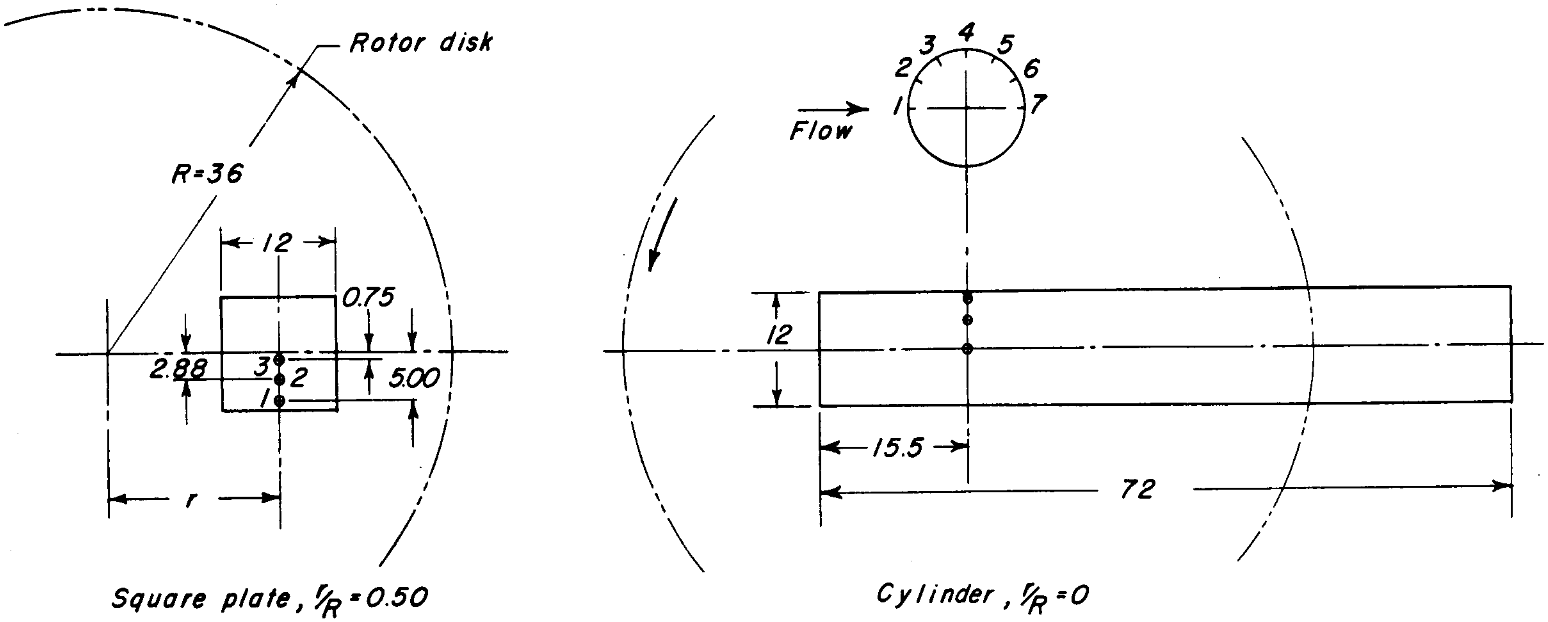
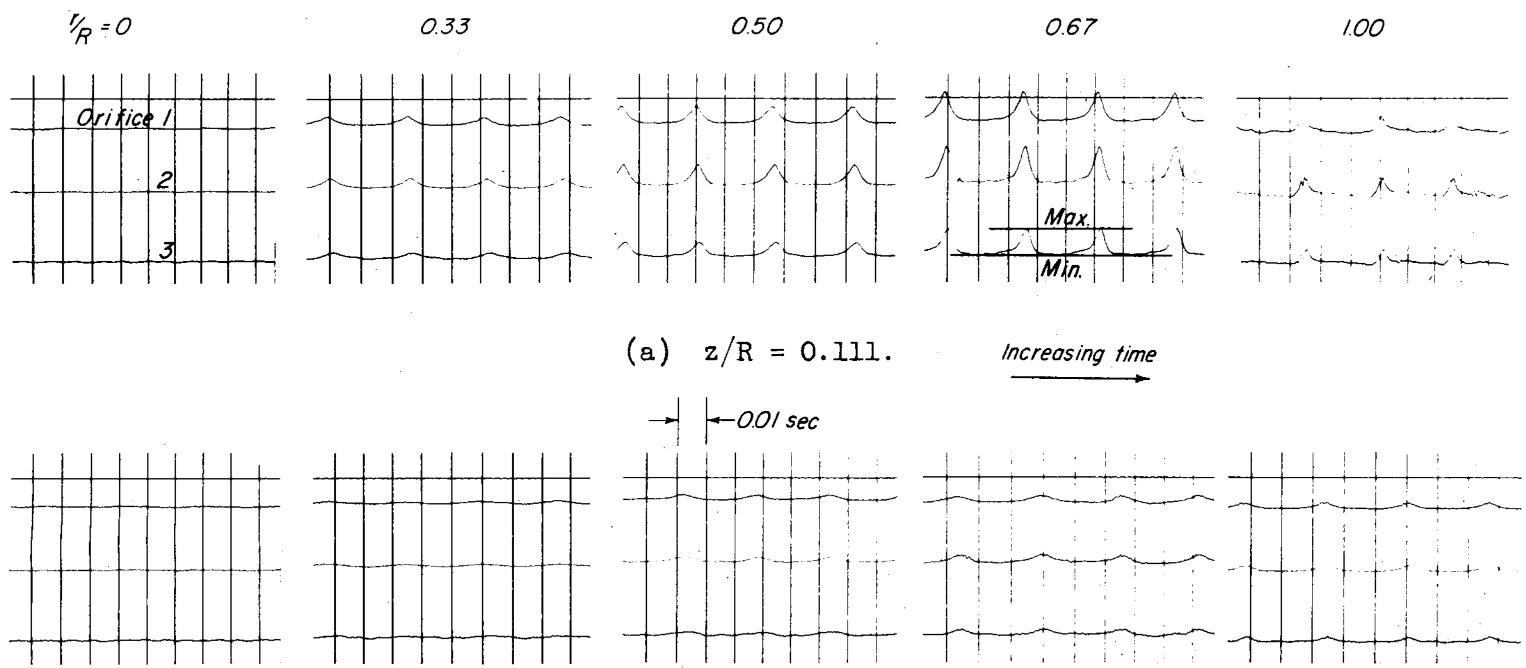


Figure 2.- Sketch of two models and location of orifices for pressure measurements. All dimensions are in inches.



(a) z/R = 0.111.

(b) z/R = 0.333.

Figure 3.- Oscillograph records of pressures for a flat plate in a rotor slipstream. Trace sensitivities are not identical.

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L-601

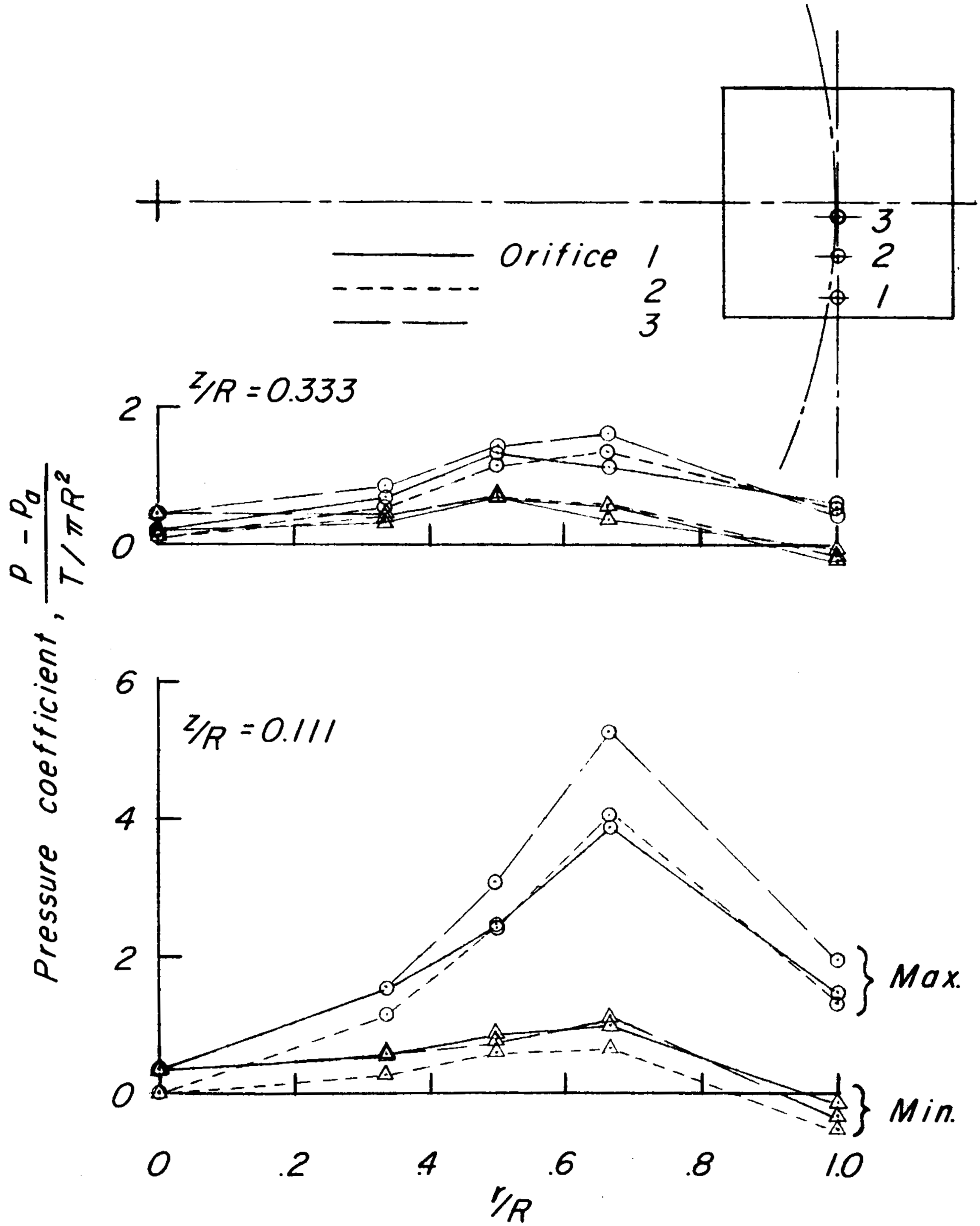
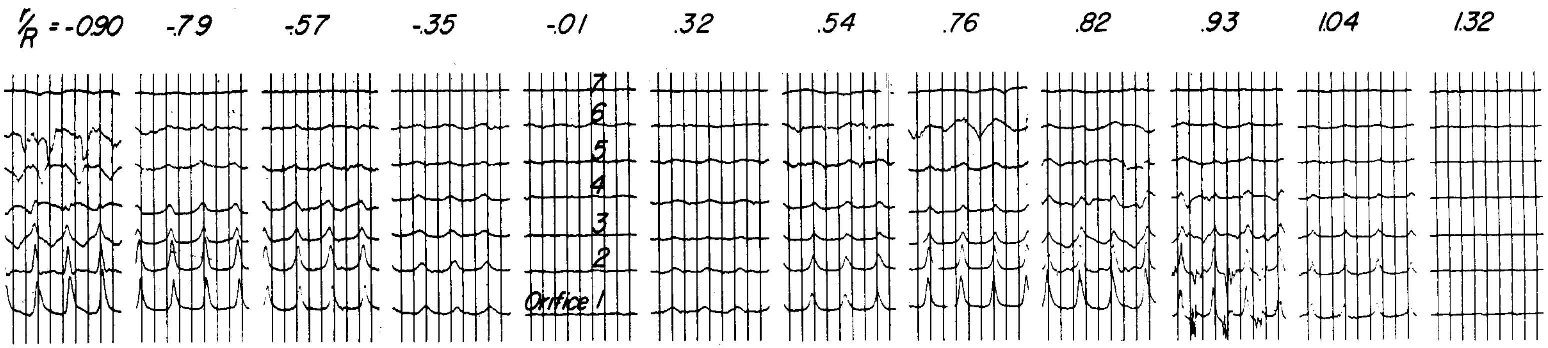
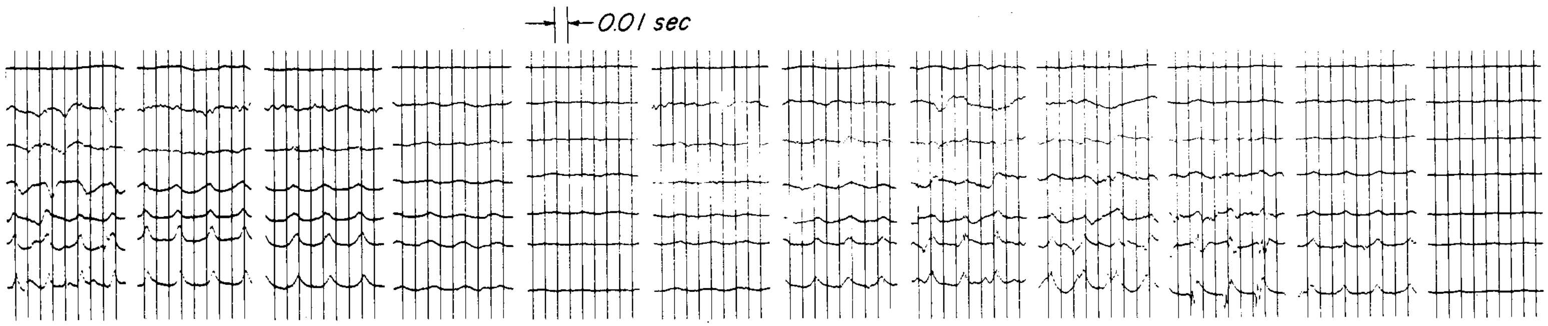


Figure 4.- Maximum and minimum values of pressure coefficient of a flat plate in a rotor slipstream.



(a) z/R = 0.278.

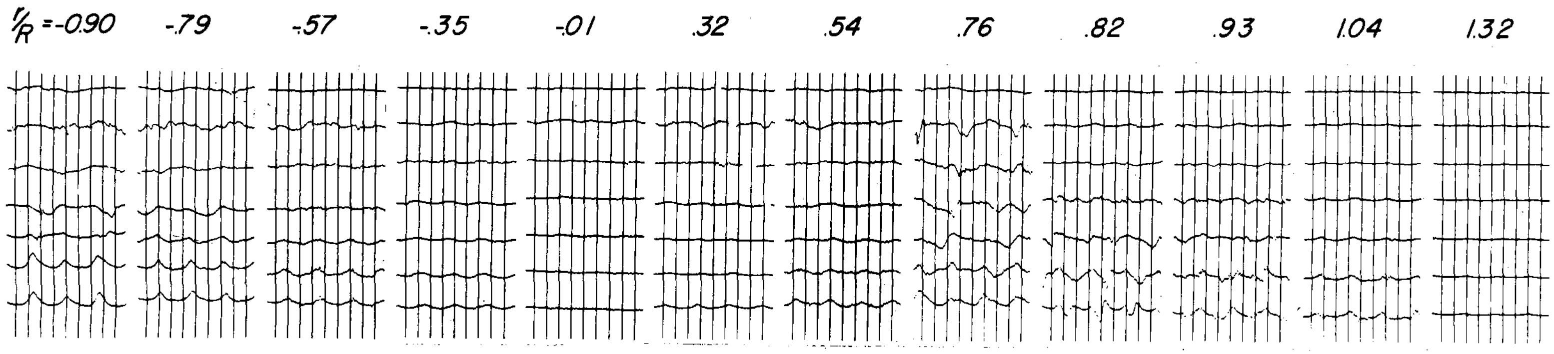
Increasing time



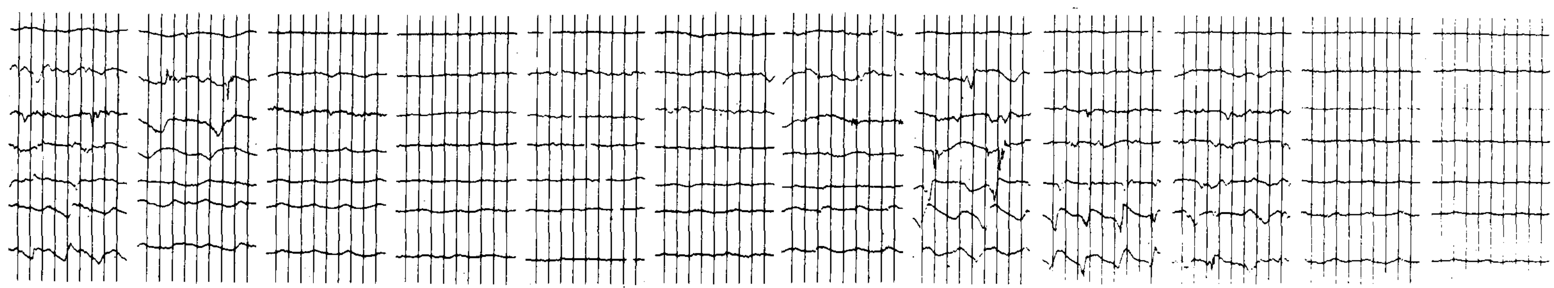
(b) z/R = 0.389.

Figure 5.- Oscillograph records of pressures for seven orifices on a semicircumference of a cylinder in a rotor slipstream. Trace sensitivities are not identical.

L-601

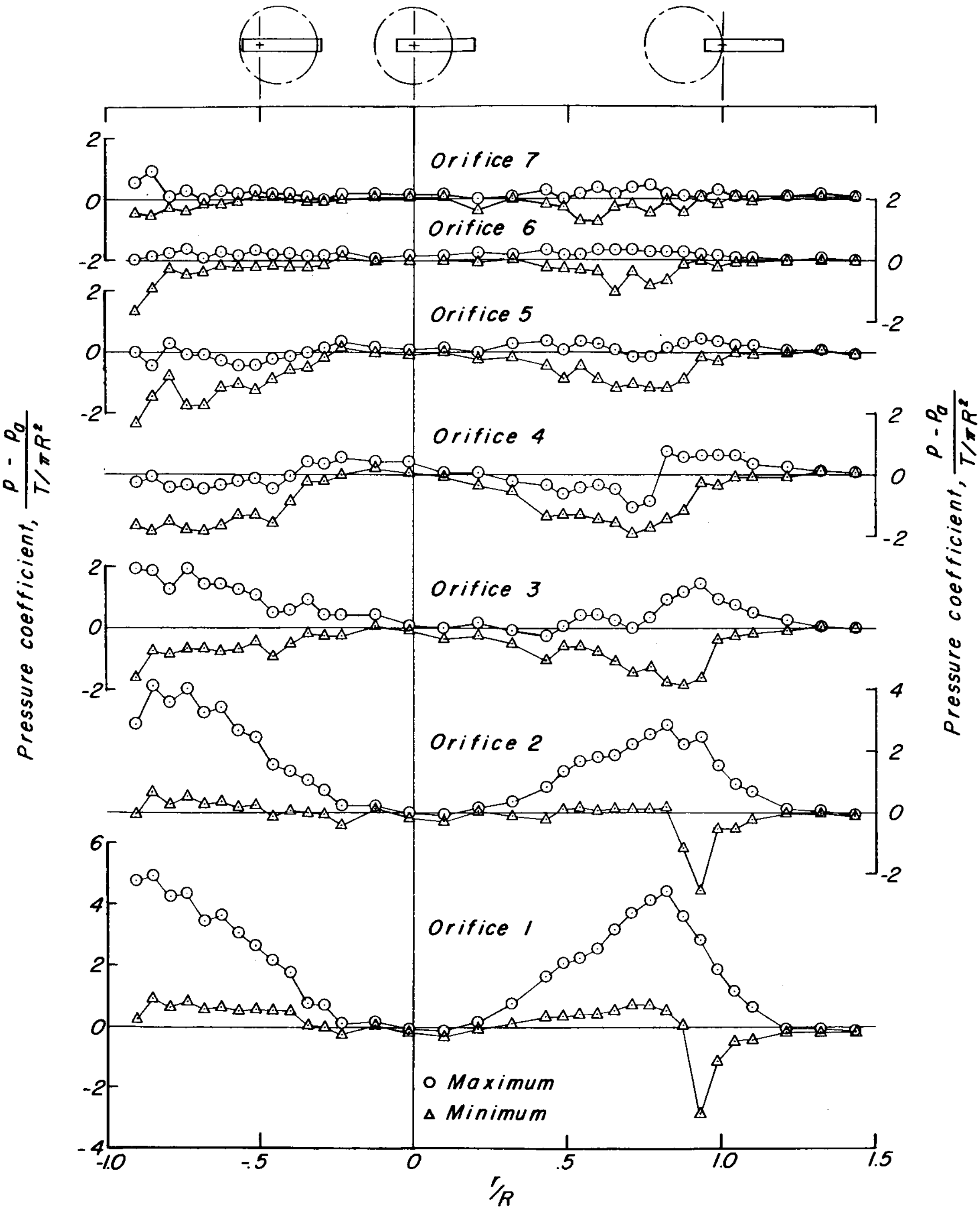


(c) z/R = 0.500.



(d) z/R = 0.611.

Figure 5.- Concluded.



(a) z/R = 0.278.

Figure 6.- Maximum and minimum values of pressure coefficient of seven orifices on a semicircumference of a cylinder in a rotor slipstream.

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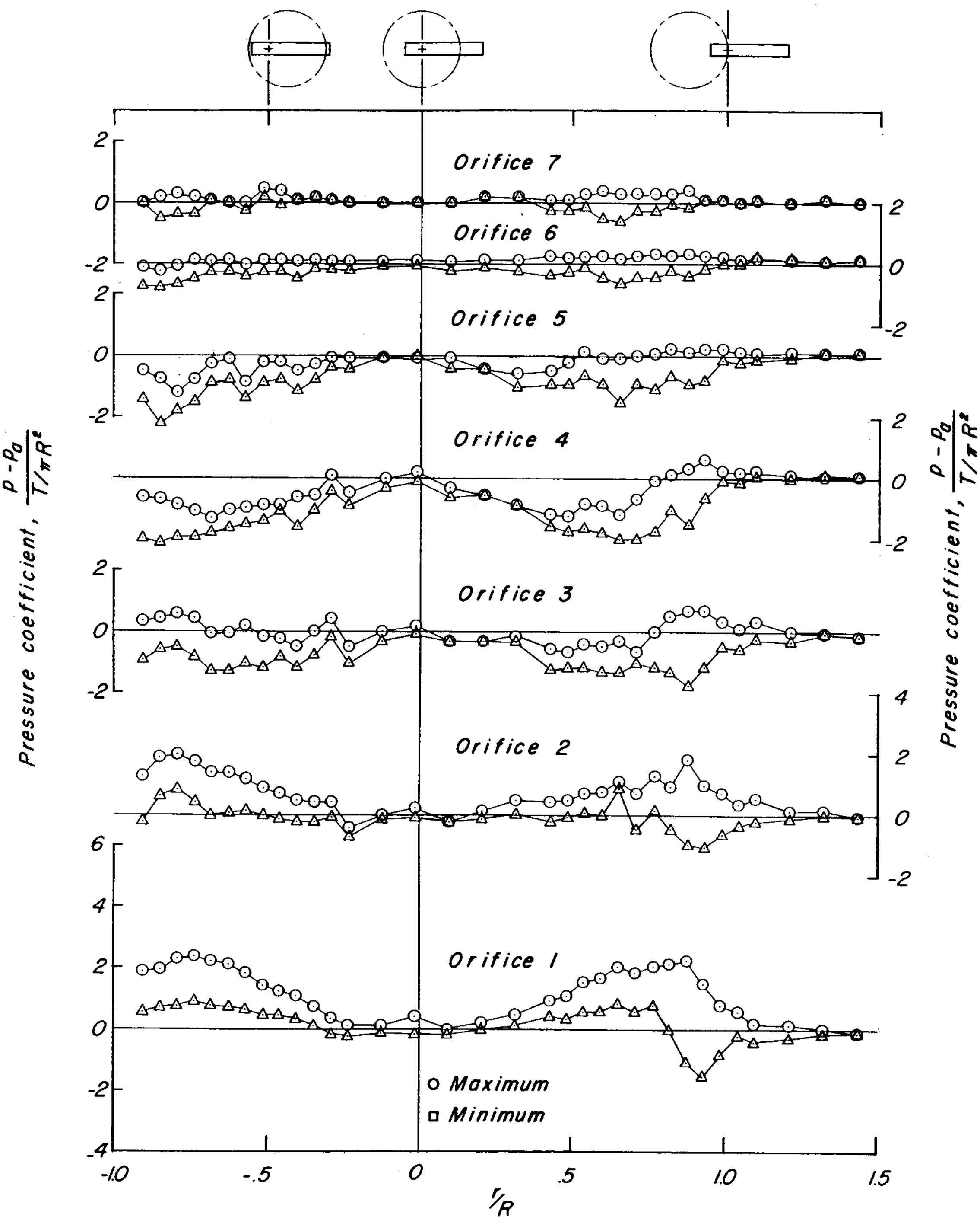
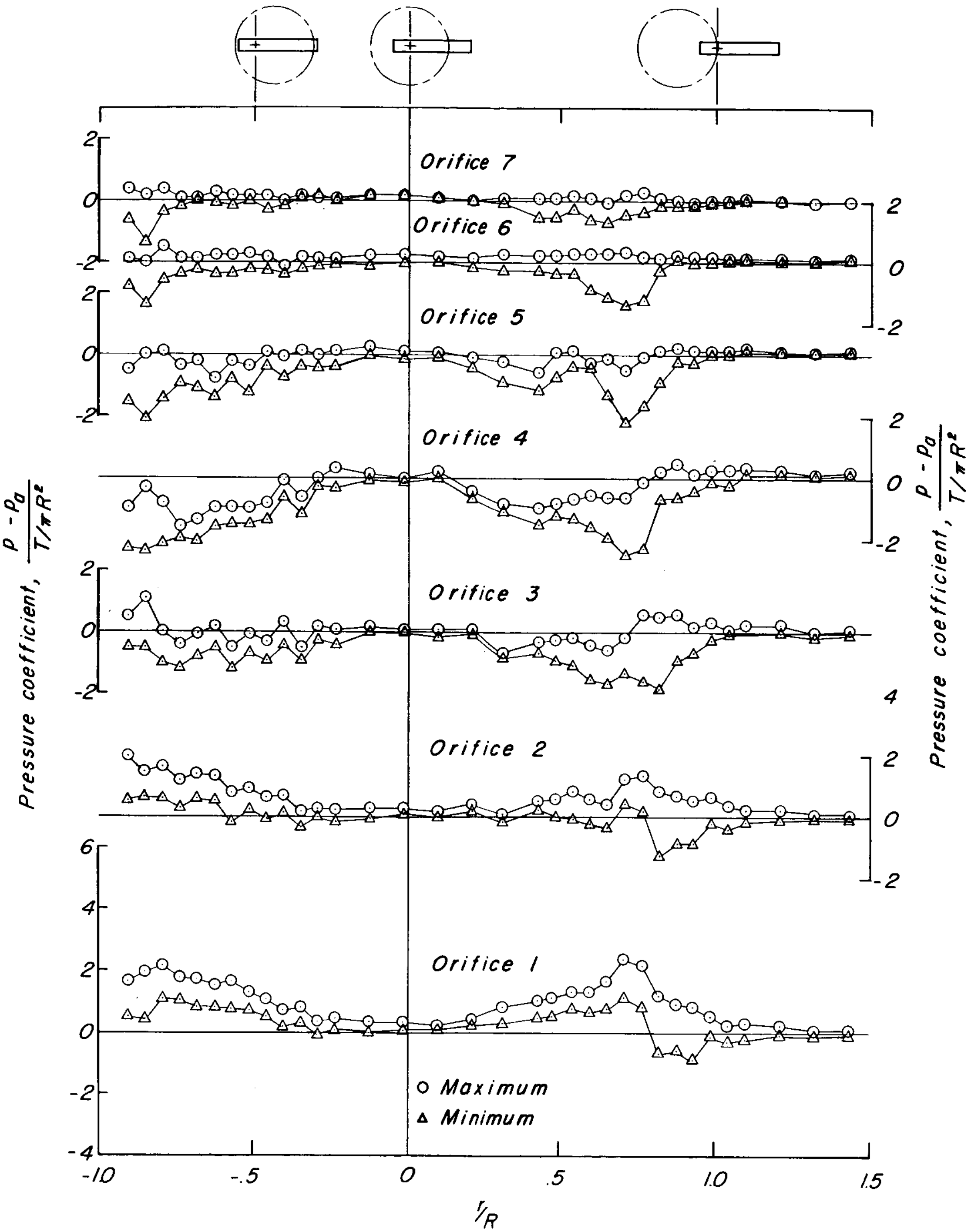


(b) z/R = 0.389.

Figure 6.- Continued.



(c) z/R = 0.500.

Figure 6.- Continued.

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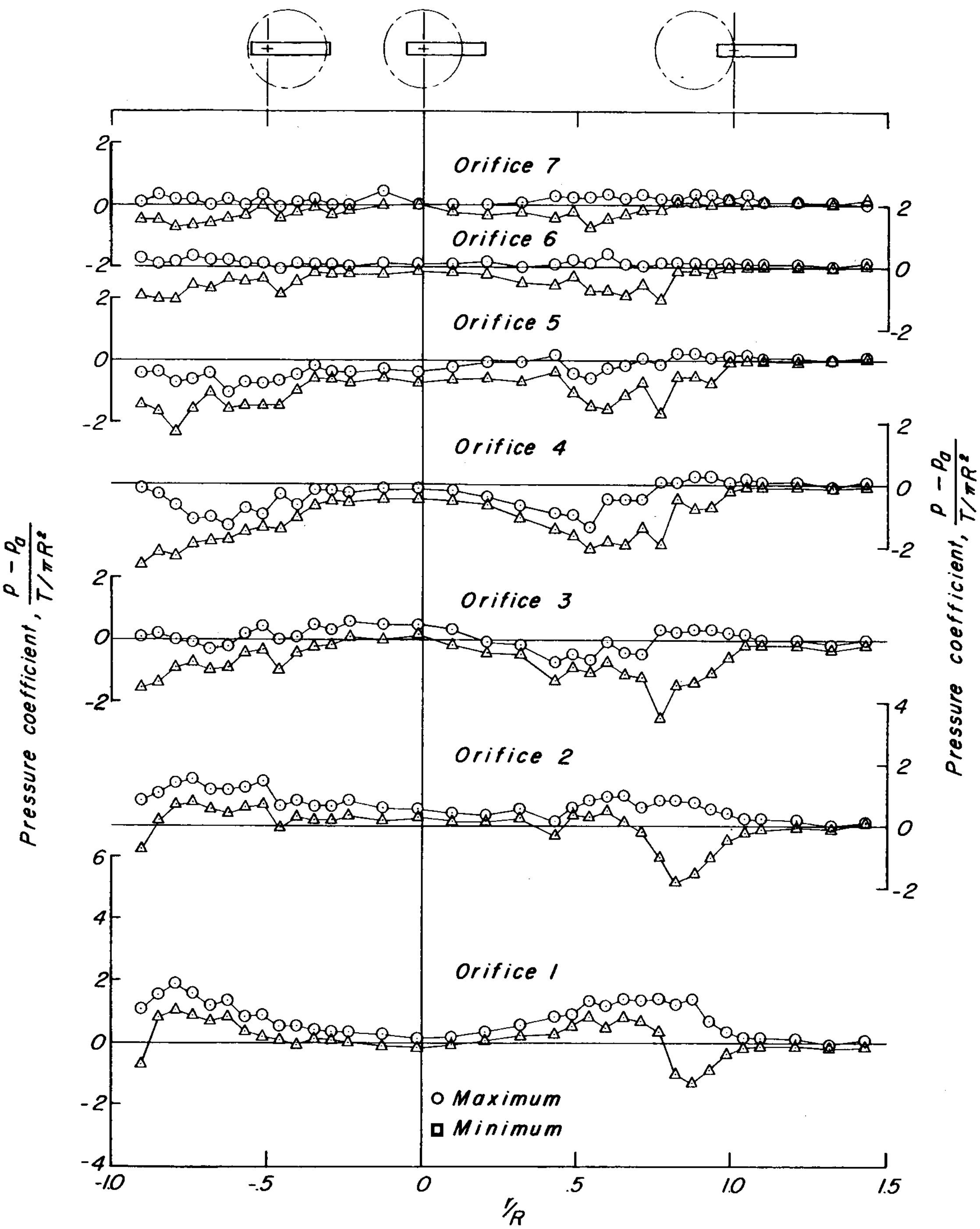

(d) z/R = 0.611.

Figure 6.- Concluded.